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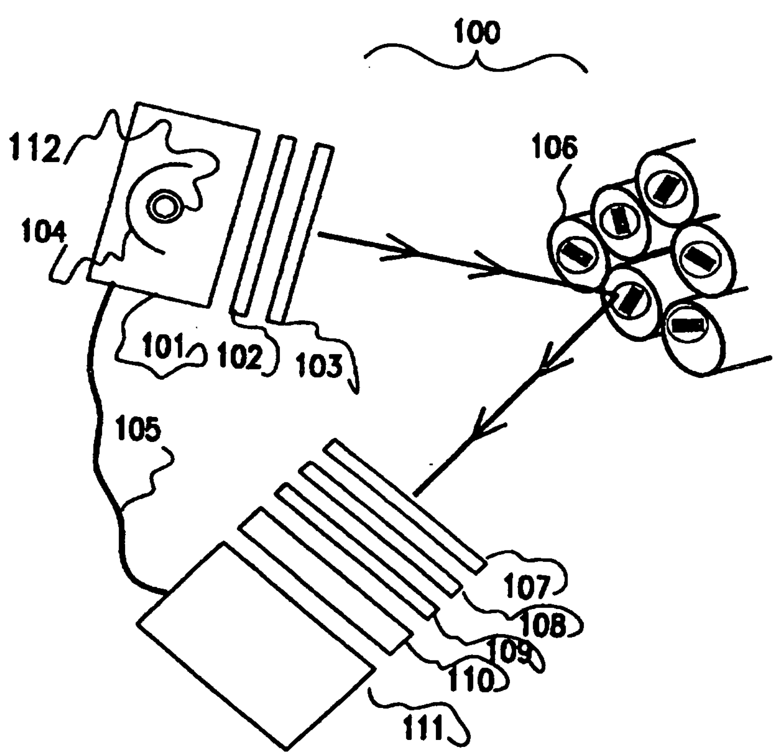
(54) Title: ELECTRONIC CAMERA WITH FAST LIQUID CRYSTAL SHUTTER

(57) Abstract

For a portable image capture application involving a need for very reliable simultaneous capture of a plurality of images of coded labels (106) each upon a varying object and under uncontrolled ambient lighting, the invention provides an electronic camera (111) and lighting elements (101) adapted to overpower the contribution of any ambient light on the captured image. Thus highlights and shadows inside recesses are similarly lit. The main device (100) is using a brief (< 100 uS, typically about 60 uS) flash of powerful light and a ferromagnetic liquid crystal shutter open only within the period of the flash. Matching spectral bands of flashed and admitted light contributes to the objective; so does linear polarizing/analyzing to reject specular reflections. The spectral limits between deep orange and infrared (at about 1 micron) also minimize the risk of startling nearby personnel, although other bands could be used.



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ELECTRONIC CAMERA WITH FAST LIQUID CRYSTAL SHUTTER

FIELD OF THE INVENTION

This invention relates to image capture means for use in the field of machine vision and data capture and in particular to improvements for overcoming environmental variations in lighting when the image capture means is used outdoors.

BACKGROUND

The inventory management application for which this invention has been designed may be regarded as a development going beyond reading a simple barcode with a hand scanner in contact with the label on an object to be identified or tracked.

The "barcode" has evolved into a two-dimensional encoded label capable of being any one of millions of unique numbers. That label has to be read from a safe distance, because of operational requirements, and at the same time the application requires that there may be a large number of labels (from two to some hundreds) at any orientation, in one field of view as captured within a single image. The reading act is to be carried out out-of-doors at any time of day or night. Sunlight or bright floodlights may cast shadows, may directly enter the port (i.e. lens) of the reading device, and may cause reflections. Rain and dirt may render the encoded data unreliable. It is not practicable to return to the site and repeat an act of reading, because the goods may have irretrievably been moved onwards. Finally, a low error rate is required; particularly in relation to minimising the number of falsely decoded readings. Thus, having good control of lighting conditions would provide a good foundation for the remainder of the process.

The prior art has been able to solve some of the above problems by using machine vision equipment in indoors environments where the lighting and other variables are controlled and where no more than a single object for study is likely to be in a single image.

This problem resembles the common use of "fill-in flash" in order to supplement the amount of light coming out of shadowed areas into an ordinary camera. This technique is widely used in portraiture. However, when machine vision equipment is used out of doors according to the application described above, the scale of the "fill-in" effect is such that a direct approach would have to produce enough energy as light to totally swamp sunlight over 18 square metres (approx) of surface and this is infeasible using commonly available equipment having a typical shutter-open duration, and flash output duration of 1 millisecond or more, because the ambient light, the contribution of which is meant to be minimised, continues to build up in the image over that period.

Evidently there is a need for an apparatus capable of repeatedly capturing images of uniformly suitable quality for machine vision purposes; principally the decoding of encoded labels represented as small details within a captured image.

Definitions:

A "working level of ambient light" is a level in which people can safely go about their transport and storage duties. A typical value is sunlight; 200 W/m^2 over an example range of wavelengths (700-900 nm) used herein, and another typical value is floodlighting to an illuminance level of about 300 Lux.

A "non-mechanical shutter" is one that has no physically moving component parts, the lack of inertial effects allowing it to reach higher on/off switching rates. The current example ferromagnetic liquid crystal shutter can open and close again within 100 microseconds.

OBJECT

It is an object of the present invention to provide an improved apparatus for capturing images for machine reading purposes of uniformly acceptable quality or one which will at least provide the public with a useful choice.

STATEMENT OF THE INVENTION

In a first broad aspect the invention provides image capture apparatus suitable for capturing, within a recording medium, an electrical version of an optical image of an object in an environment having a working level of ambient light, the recording medium comprising an array of solid-state photosensitive units, characterised in that the image capture apparatus includes means capable of emitting a controlled quantity of light of a controlled intensity and duration towards the object for a brief period not exceeding five hundred microseconds and means substantially capable of excluding from the image that light collected from the object which was not emitted by the emitting means during that brief period so that the captured image is built up primarily from light scattered from the controlled quantity of light.

Preferably the brief period is less than 250 microseconds, and more preferably the brief period is less than 100 microseconds. Even more preferably, the period of time for the flash - when a substantial majority (70%) of the light is emitted is about from 20 to about 65 microseconds after a trigger pulse commences.

Preferably the brief period of time during which flash light is produced by the flash lamp means is short, so that the proportion of integrated ambient light incident on the CCD (the transducer) is low in relation to the proportion of integrated flash light incident on the transducer, during the period of time.

A preferred shutter means is a fast, ferromagnetic liquid-crystal shutter. Another implementation of a shutter means is a gated microchannel image intensifier.

In a first related aspect the invention provides image capture apparatus as described above, wherein the means substantially capable of excluding from the image that light collected from the object which was not emitted by the emitting means includes means capable of restricting the spectral bandwidth of the collected light to light of a wavelength ranging between a first upper limit and a first lower limit.

In a subsidiary aspect the invention provides image capture apparatus as described above, wherein the means capable of emitting a controlled quantity of light towards the object includes means capable of restricting the spectral bandwidth of the emitted light to light of a wavelength ranging between a second upper limit and a second lower limit.

In another subsidiary aspect the invention provides image capture apparatus as described above, wherein the range between the first upper limit and the first lower limit and the range between the second upper limit and the second lower limit overlap to at least some extent.

In a second related aspect the invention provides image capture apparatus as described above, wherein the means substantially capable of excluding from the image that light collected from the object which was not emitted by the emitting means includes means capable of restricting the angle of linear polarisation of the collected light to light having a first angle of polarisation.

In a subsidiary aspect the invention provides image capture apparatus as described above, wherein the means capable of emitting a controlled quantity of light towards the object includes means capable of restricting the angle of linear polarisation of the light to light having a second angle of polarisation, substantially perpendicular to the first angle of polarisation.

In a third related aspect the invention provides image capture apparatus as described above, wherein the means capable of emitting a controlled quantity of light towards the object includes means capable of restricting the duration of the emitted light to a defined period between a first moment and a second moment, and wherein the light emitted during the defined period is of an intensity sufficient to dominate the ambient light present in the environment.

In a subsidiary aspect the invention provides image capture apparatus as described above, wherein the means capable of emitting a controlled quantity of light towards the object comprises a gas-filled flash tube capable of producing a brief flash of light of known duration, connected to control means for triggering a discharge in the flash tube, and connected to supply means capable of storing a controlled amount of electricity for discharge in the flash tube.

In another subsidiary aspect the invention provides image capture apparatus as described above, wherein the means substantially capable of excluding from the image that light scattered from the object which was not emitted by the emitting means includes fast-acting shutter means capable of restricting the duration of the collection of light to a period of up to a tenth of a millisecond.

In a fourth related aspect the invention provides image capture apparatus as described above, wherein the means substantially capable of excluding from the image that light collected from the object which was not emitted by the emitting means comprises means to capture a pair of

images of the object; only one of which is illuminated by light emitted by the means capable of emitting light, and subtracting one image from the other image, thereby deriving the difference between the two, so that the difference image incorporates the illumination derived from the emitted light.

Preferably the flash lamp is provided with a reflector optimised for high reflection in the near infra-red range, and preferably this employs a gold reflecting surface.

Preferably the spectral bandwidth includes those wavelengths lying between about 650 microns and about 1000 microns when the dominant optimising requirement is to avoid using visible light in the flash output.

Alternatively the shorter wavelength may be extended to about 550 microns (mid-orange) when the dominant optimising requirement is to increase the amount of light to be used.

Alternatively, the shorter wavelength may be extended to the full extent of the CCD sensitivity range (about 400 microns) when the dominant optimising requirement is to increase the amount of light to be used and visibility of the flash is of no importance.

Alternatively the system of flash light source and camera may work over any matched narrow band of wavelengths.

In a second broad aspect the invention provides an image capture apparatus as described previously in this section, in which the flash light produced by the flash lamp means is concentrated within one or more bands of the spectrum of active wavelengths.

In a consequent aspect the flash light incident on the transducer is filtered by transducer filter means so as to permit light of the relevant band of wavelengths to pass to the transducer, and to substantially block other light, so that the relative effectiveness of the light from the flash lamp as compared to ambient light means is enhanced.

Preferably the one or more parts of the spectrum include the red and more preferably the near infra-red portions of the spectrum; that is, substantially in the range of from 600 to 900 nanometers (nm) wavelength.

A preferred flash lamp for use in the flash lamp means includes a flash tube filled substantially with xenon and/or other rare gases including neon and krypton. Preferably the flash lamp is filled to a pressure of about 350-450 torr. Preferably the high voltage is of the order of 1300 to 1800 volts; preferably 1500 volts.

Preferably the quantity of charge used in each discharge of the flash lamp means is sufficient to render the light from the flash lamp means relatively brighter than the ambient light, under conditions as described within this section, and is also sufficient after reaching the object to provide an adequate amount of integrated flash light incident on the transducer.

In a third broad aspect the invention provides an image capture apparatus as described in either or both of the first and second broad aspects of this section, for which a first light polarising means capable of linearly polarising light transmitted through the light polarising means is placed between the flash lamp means and the object.

In a related aspect a second light polarising means capable of linearly polarising light transmitted through the light polarising means is placed between the object and the image transducer means, and the orientation of this second light polarising means is substantially perpendicular to that of the first light polarising means.

Conveniently, the polarising filter that comprises part of the FLC shutter may serve as the second light polarising means.

In a further broad aspect the invention comprises camera means designed to reject sunlight in a captured image which camera means operates by an alternative process comprising subtraction of an image that includes flash illumination from a near-simultaneous image that does not include flash illumination.

Preferably the subtraction process is carried out within a modified CCD chip including means to compare two images.

Alternatively the subtraction process may be carried out using two CCD chips viewing the same image in registration by means of a beam splitter, each CCD having a FLC shutter in front and each FLC shutter being driven in sequence so that preferably one CCD captures an image immediately prior to flash lamp activation, and one captures an image during flash lamp

activation.

DRAWINGS

The following is a description of a preferred form of the invention, given by way of example only, with reference to the accompanying diagrams.

Fig 1: is a block diagram of an image capture apparatus according to this invention.

Fig 2: is a block diagram of a flash lamp of the present invention.

Fig 3: illustrates the relationship between the FIR shutter opening and the flash lamp output (as detected by silicon photodiodes) according to this invention.

Fig 4: illustrates example filter pass bands for an image capture apparatus according to this invention.

PREFERRED EMBODIMENT

This invention comprises image capture apparatus intended for capturing images of multiple encoded labels in outdoors conditions. It is desirable that every "photograph" is totally adequate for the purpose of decoding the many labels represented within it; the image capture procedure cannot be repeated without a great deal of organisation such as unloading a ship or recalling a timber lorry.

The invention was devised to capture images for recording logs of wood during shipment. A cradle perhaps 6 metres wide filled with logs to a height of up to 2 or 3 metres (12 - 18 m^2, their ends presented to the camera operator at a fixed range of about 6-7 metres and each bearing an attached label is recorded before the cradle is lifted onto a ship with one high-resolution image at each side of the cradle. The image is later automatically dissected. Information returned includes the contents of each and every label, and the total number of log ends in each picture. The picture capture rate can be about per hour in a typical wharf, and the battery life of the camera is about 2.5 hours of such use. Camera usage rates: typical rate is a pair of images every 5 minute cradle cycle, but a rate of up to one frame per 35 sec can be sustained. The image downloading time of 30 sec limits this rate. Up to 400 or more flashes can be taken from

a 2.5 hour battery pack, although preferably less depletion of the lead-acid battery improves battery life.

The problems related to collecting consistent images of adequate quality include that variable ambient illumination - either natural or floodlighting - may supplement or detract from artificial (flash) illumination, and may cause shadows, reflections, or glare. Artificial illumination from a flash may dazzle and startle, may cause eye damage, will require a power source, and adds to expense. Modifying a camera complicates the assembly, adds to its expense, and detracts from its "off-the-shelf" availability. Camera modification may detract from usability; for example, if the through-the-lens viewfinder is rendered unusable.

A major part of the invention involves overcoming sunlight (or other ambient lighting of similar intensity) with a brief flash concentrated in near infra-red wavelengths and a camera that receives only light of that spectral range at that time. Because the flash energy - sufficient of course to give an adequate exposure - is concentrated in a shorter and shorter period of time, then providing the camera is made to accept light over only a matching period or "acceptance time", the steady contribution of sunlight (which would itself provide an adequate exposure over a longer, fixed period) becomes less and less important. It is feasible to provide the flash energy in a 100 to 200 µsec pulse, rather than the usual 4 to 5 msec pulse for photographic use. (Actually, most of the flash has been emitted within 65 microseconds of the trigger pulse). Reciprocity failure (as seen in the silver halide emulsions of conventional photography) is not a characteristic of CCD arrays.

A similar approach could be used in relation to the spectral distribution of the light in order to minimise the contribution of sunlight; ideally a monochromatic source and a matching, narrow-band camera filter.

Although an "optical radar" or "LIDAR" solution, in which a brief laser pulse is emitted and a shutter is opened for only that period corresponding to the range of flight time of the reflected photons could be used, as in underwater viewing, the Q-switched laser technology involved is particularly unlikely to be acceptable in a transport yard where vision of the personnel is placed at risk. Intense, pulsed, monochromitic sources such as a Q-switched ruby laser (used together with a camera having a matched time and wavelength "window" could solve the problem only if cost, hazards, and size were no object.

The above procedures, involving the use of lasers as light sources and their use is impractical given the constraints of our preferred application, namely man-carried equipment and the likeliness that others are likely to suffer eye damage or be startled by laser flashes.

We selected flash tube light sources as convenient, powerful sources.
The band of the spectrum that any particular installation may use depends on a number of factors, and human factors predominate.

Originally we selected the deep red and near infra-red region of the spectrum partly because, although this region is suitable for use with silicon sensors, it is substantially invisible to the eye, yet still suited to conventional camera optics; lenses and filters. Use of infra-red flash equipment in a busy loading yard is unlikely to dazzle or startle operators of equipment. Restriction of wavelengths also assists in minimising the contribution of ambient light to the captured image.

We have found that on a busy wharf where the level of ambient lighting even at night is of the order of 300 lux, that a visible flash even including orange light is a safer selection. This shows other workers that a cameraman is working. Orange flashing beacons are commonly used on wharf vehicles and the like. Furthermore, there is probably more risk of retinal damage if a substantially invisible flash is used. People will peer at it to see if it is actually working, and the unconstricted pupil may admit a dangerous amount of energy. Therefore we now prefer a wider band of the spectrum.

(Of course if this equipment was to be used in a situation where flash light was unlikely to affect other users, such as in automatically recording the contents of a loaded vehicle where no person is likely to be in the flash-illuminated area, it may be preferable to use the full spectrum of light that is emitted by a flash tube and can be used by the CCD chip, or alternatively restrict it to bands in shorter wavelengths only (green/blue to blue) in order to get increased resolution.

Polarised light assists in rejecting reflections from shiny surfaces or droplets.

PREFERRED EMBODIMENT

FLASH TUBE

This item is a particularly useful link in the chain because it produces a usefully brief flash, momentarily brighter than ambient light yet does not have the complexity or hazards of an equivalent laser source. (By "usefully brief" we mean that a flash duration of less than 100 µS (together with a fast shutter of course) can distribute enough peak energy without undue consumption of average energy. Hence battery life is not a great problem.

We prefer to use a krypton filling in the flash tube because this gas (at least at a filling pressure of 750 torr) provides enhanced output in the near infra-red range over the output from a more conventional xenon filling. The filling is likely to contain a proportion of xenon because the gases are separated out together from air in a cryogenic plant. However, xenon types are readily available. The tubes actually in use are made to order by EG & G and have a proprietary filling. They are supplied with an external triggering wire wrapped around the tube. The flash power used in this invention is said to be about 25% of their explosion limit.

REFLECTOR

We prefer to use a vapour-deposited or electroplated gold coating on the reflector surfaces, because gold is better than a conventional aluminium reflector in this infra-red region of the spectrum. Usually the gold is placed over bright nickel plating, and that in turn is plated onto a bright (polished) stainless steel. Silver is also preferable to aluminium, which tends to reflect ultraviolet better.. Gold and silver coatings can be protected in various ways, such as by over-coating with a hard transparent layer, or by placing them on the rear of a shaped glass surface.

JOULES

The charge storage or power of the flash is set by the requirement to effectively swamp sunlight during the flash - after taking into account losses in light caused by reflections or absorbtion in the flash optical chain and in the camera optical chain. One upper limit relates to eye safety in that even an invisible flash of sufficient intensity may cause damage to the retina by means of heat or unknown effects. Another upper limit relates to power consumption, because it is

intended that this camera and flash be portable, and run from batteries. A further upper limit relates to cost; where higher capacity generally equates to higher costs. Yet further upper limits include weight, and the maximum current that can be carried by the flash tube. The minimum requirement can be set by determining the photon flux that should arrive at the CCD (after all filtering and reflection and focusing stages) in order to obtain an adequate CCD image with minimal noise content.

A preferred power is from 200 to 400 Joules. Fig 2 indicates the parts of the flash assembly. 206 is a storage battery. 202 is a high-voltage generator to charge up the capacitors 203. 204 is a flash tube (actually a straight tube, not a "U" shape as drawn). 205 is trigger circuitry, synchronised by a line 105 from the camera.

If an image intensifier, preferably a gated one such as a microchannel plate, perhaps a "Channeltron" type using electrostatic focusing, was used, this energy requirement is lessened. At the present time suitable versions are unduly expensive.

DURATION

A duration of under 100 microseconds can be achieved by using high-voltage storage capacitors preferably with minimised loss resistances. (The charge voltage is about 1300-1800 V; preferably stabilised at about 1500 V). An air-cored inductor is placed in series with the lamp and adjacent to it, in order to extend the flash time a little. Shorter flash durations increase the relative amount of blue and ultraviolet light emitted from the gas. The actual flash duration is: peak reached 35 to 40 μS after the trigger pulse; 70% of the light has been delivered by 65 μS. The flash lamp circuitry is conventional, powered from a storage battery, and the lamp is preferably triggered (as is the FLC shutter) from the camera's shutter contact. Shorter flash periods mean higher tube currents and very short tube life.

CAMERA

The camera is a type of CCD array camera. While the preferred type (DCS 420 IR) is a variant of a "KODAK" camera - comprising a modified "Nikon" camera body having a "Nikon" 20 mm wide-angle lens and a CCD with a resolution of about 1500 x 1000 (high) pixels, the invention may be used with other types of camera and with other lenses or image-forming mirrors. Photographic film or at least the silver halide emulsion of photographic film may

exhibit anomalous sensitivity (known as reciprocity failure) when used with brief illumination.

SHUTTER

This item is a useful link in the chain because by being open for only about the duration of the brief flash it limits the integration of background light and hence the flash light is relatively dominant. (By "usefully brief" we mean that a shutter duration of less than 100 µS (together with a fast flash of course) can receive enough distributed enough peak energy to capture self-illuminated scene in daylight without undue consumption of average energy. Hence battery life is not a great problem.

A fast (ferromagnetic) liquid-crystal (FLC) shutter, type made by Displaytech Inc, Boulder Colorado) capable of switching states in under 35 microseconds is used to minimise ambient light contributions to the integrated exposure on the CCD array. Even direct sunlight does not provide adequate exposure with a short shutter speed of typically 100 µS. The FLC shutter involves the use of polarisation filters and a material whose polarisation can be rotated quickly by the application of an electric field. The shutter is driven so that it is at a peak transmission mode at the moment when the intensity of the flash is at its peak.

A useful modification to this shutter is to provide compensation for cool environmental temperatures, (such as 15 deg C) when the speed of the shutter falls far below usefulness. We have screwed resistive heaters to each side of the aluminium ring and heat them with up to 15W of power when required. An integrated-circuit temperature sensor of the 1 mV /deg K type is used to sense temperature. One function of the microprocessor in our camera support circuitry is to monitor the temperature of the FLC shutter and apply heat and prevent use of the camera if the shutter is too cold. The control loop maintains the shutter at between 25 and 35 deg C.

Fig 3 illustrates an oscillogram of the timing relationships obtained. The mechanical shutter of the camera is open for the entire period depicted. Each vertical line represents 50 microseconds. The line 301 is a silicon photovoltaic cell output depicting the transmittance of the FLC shutter. The line 302 represents the emission from the flash tube as detected by a silicon photovoltaic cell. Note the elongated tail on the flash emission. This may represent infra-red emission from hot gas or may represent a delayed glow of current.

As an alternative, a CCD chip having enhanced shuttering means (a control lead to the chip

which enables or disables sensitivity to light) could be used, but the selected camera may need substantial modification in order to use such a chip. It is possible that CCD chips in which the sensitive period may be as short as 50 μs (or less) can become available. In the meantime, a FLC shutter permits a short exposure without modification of the DCS 420 IR camera.

As a further possibility as an alternative to a FLC shutter, the CCD chip may be optically linked to a gated, high-resolution microchannel plate which is a type of image intensifier. In this application the microchannel plate may be operated at a low gain in order to minimise photon noise and irregularities (caused by gain variations) over its surface. Microchannel plate devices may be gated so that they accept images over periods of as short as 40-80 nanoseconds. Furthermore, the photocathode sensitivity may be optimised within the infra-red region so that a less powerful flash is needed; or alternatively (and perhaps with raised gain) so that a narrow-band bandpass filter such as an interference filter can selectively admit an emitted spectral line.

The ordinary shutter of the camera is preferably operated in conjunction with the FLC shutter (or other shutter/gated device). Because a FLC shutter does not totally block light when closed, support by the ordinary shutter is useful. Thus the most desirable operating mode is to synchronise the flash with the moment when the ordinary shutter has revealed the total active area of the CCD chip surface.

COLOUR FILTERS

We have had some difficulty in acquiring filters having optimal "colours" or light transmission properties and the set to be described is purely an example. We found it useful to select filters according to manufacturers' descriptions, and then to actually check the chosen filters singly or in combination using a tunable source of light from a monochromator, viewed by the intended type of camera, over a wide spectral range from ultraviolet to infra-red light. This technique revealed a number of unanticipated transmission bands, such as in the far infra-red, which would have degraded the image.

Also, we would prefer to use a filter over the actual CCD chip itself within the camera, rather than one over the lens, so that viewfinder brightness stays high while the CCD receives only light from the intended band of wavelengths. To date, we have preferred not to modify the camera at that level.

Fig 1 shows one preferred combination of filters. It appears that some far infra-red light still active on the CCD device is admitted by this set and this light tends to degrade image contrast.

In Fig 1, 100 is the entire optical train. 101 is the flash unit, containing a gold-surfaced reflector and a flash tube 112. 102 represents a "Kodak 1A" darkroom safe light gel sheet (orange-red; curve 406- Fig 4) and 103 is a polarising sheet filter. There is also a "Lexan" clear polycarbonate face plate which is believed to have no significant effect. After reflection from labels on merchandise 106, the light passes to the camera where it is filtered by a 1000 nm high-pass filter 107 (blocking light beyond 1000 nm) and by an 800 nm high-pass filter 108 (blocking light beyond 800 nm) (the latter appears to admit light beyond 950 nm hence we also use the 1000 nm filter). 110 represents the transmittance of the glass optics, and 111 is the CCD chip itself. In use, the "1A" gel suffers some ultraviolet degradation from the flash tube and can be replaced from a stock of sheet gel.

Fig 3 also shows at 403 the emission pattern of an xenon flash tube with 450 torr pressure. (This depends somewhat on the Joules used.) At 404 a krypton emission pattern is shown; this has higher output in the selected pass band indicated as 408.

Our original intention was to use substantially invisible flashes for an application that more or less dictates that image capture shall be performed with illumination invisible to humans, so that personnel driving cranes and the like are not distracted or blinded by flashes of visible light. We prefer for our wharf lading application to use flashes which appear as red or orange flashes; this enhances safety because other personnel are then aware of a working cameraman. In other applications, where the "startle" effect is not important, it may be preferable to use shorter wavelengths of light hence achieving more light utilisation or a higher resolution.

POLARISING FILTERS

Specular reflections, such as those arising from a shiny black ink printed onto an encoded label, or from droplets of water over the surface of a label, are reduced using polarising filters, using the well-known mechanism that specular reflections (off shiny surfaces) retain much if not all the original plane of polarisation of the incident light, whereas reflection involving much scattering of light within a light matte or diffusing surface loses its original polarisation. Hence specular reflections can be largely eliminated by viewing a surface, illuminated by light polarised in one plane, through a second polarising filter oriented at right angles to the first.

Circular polarising filters result in a similar effect.

Because the FLC shutter relies on polarisation and inherently adds a polarising filter to the optical chain in the camera, we can conveniently add one more polarising filter with its plane of polarisation at right angles to the shutter filter over the flash lamp and thereby implement a useful reduction of specular reflections. We set up the polarising filter over the flash by observing the reflection of a halogen lamp, while shining through the flash housing, in a mirror and rotating the flash polariser until the reflection, which has passed through the polarising filter (analyser) FTC shutter is of minimal intensity. This has the effect when in use of reducing reflections from shiny surfaces, because those tend to retain polarisation, while well-scattered light returned from a label surface, for example, has substantially lost its polarisation.

Certain types of polarising filter have acceptable polarising activity in near infra-red light and acceptable transmission. We have found that type LIR 40, type HN22, and type HN32 filters polarise infra-red light.

IMAGE PROCESSING SOLUTION TO REJECTION OF AMBIENT LIGHT

Given that this invention is intended to impose its own lighting on an environment and thereby dominate any ambient lighting, it is possible to accomplish this effect with a two-exposure system and a relatively weak light source, together with an adequate dynamic range within the imaging system.

Here the principle is to take a pair of images of a subject; sufficiently close together in time and space to be substantially identical, except that in one of them the camera emits its own light. Then, by image-processing techniques of some type the image based solely on ambient light can be subtracted on a pixel-by-pixel basis from the image also including the added camera light, leaving an image based on added light alone.

Possibly the subtraction process is carried out within the camera - using a modified CCD chip which can shift a first image into non-sensitive wells, immediately capture a second image, and read out the two images simultaneously to a charge amplifier/buffer device including an analogue subtraction function.

Alternatively the subtraction process may be carried out using two CCD chips viewing the

same image in registration by means of a beam splitter, each CCD having a FLC shutter in front and each FLC shutter being driven in sequence so that preferably one CCD captures an image immediately prior to flash lamp activation, and one captures an image during flash lamp activation.

Alternatively the two images may be handled normally and subtracted from each other within a separate computer running a suitable image processing software program.

ADVANTAGES

Assuming that it has been decided that ambient lighting must be brought under control in some way, this technique using a very short picture-taking time allows ambient lighting to be swamped without the expenditure of a great amount of energy. Up to 400 or more flashes can be taken from a man-carried 2.5 hour battery within the equipment backpack, although preferably less depletion of the lead-acid battery improves battery life.

The camera is in use in the "MORIS" system for tracking and inventory control of logs during shipping within the New Zealand timber industry.

Finally, it will be appreciated that various alterations and modifications may be made to the foregoing without departing from the scope of this invention as set forth in the following claims.

CLAIMS

1. Image capture apparatus suitable for capturing, within a recording medium, an electrical version of an optical image of an object in an environment having a working level of ambient light, the recording medium comprising an array of solid-state photosensitive units, characterised in that the image capture apparatus includes emission means capable of emitting a controlled quantity of light of a controlled intensity and duration towards the object for a brief period not exceeding five hundred microseconds and blocking means substantially capable of excluding from the image that light collected from the object which was not emitted by the emitting means during that brief period so that the captured image is built up primarily from light scattered from the controlled quantity of light.

2. Image capture apparatus as claimed in claim 1, characterised in that the blocking means comprises fast-acting non-mechanical shutter means capable of restricting the duration of the collection of light to the brief period.

3. Image capture apparatus as claimed in claim 1 characterised in that the brief period is less than 100 microseconds.

4. Image capture apparatus as claimed in claim 1, characterised in that the emission means includes means capable of restricting the duration of the emitted light to a defined period between a first moment and a second moment, and characterised in that the light emitted during the defined period is of an intensity sufficient to dominate the ambient light present in the environment.

5. Image capture apparatus as claimed in claim 4, characterised in that the emission means comprises a gas-filled flash tube capable of producing a brief flash of light of known duration, connected to control means capable of triggering a discharge in the flash tube, and connected to supply means capable of storing a controlled amount of electricity for discharge in the flash tube.

6. Image capture apparatus as claimed in claim 1, characterised in that the blocking means includes fast-acting shutter means capable of restricting the duration of the collection of light to a period of up to 100 microseconds, substantially synchronised with the light emitted from the flash tube.

7. Image capture apparatus as claimed in claim 1, characterised in that the emission means includes means capable of producing light having a restricted spectral bandwidth, being light of a wavelength ranging between a first upper limit and a first lower limit.

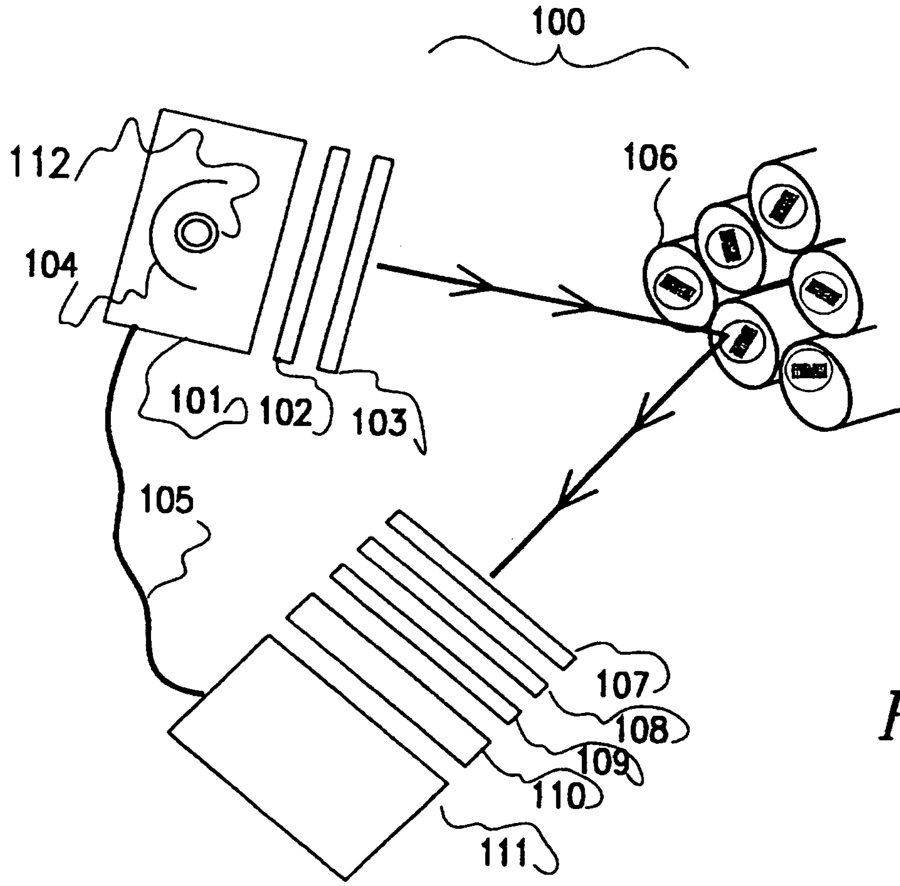
8. Image capture apparatus as claimed in claim 1, characterised in that the blocking means includes means capable of restricting the spectral bandwidth of the collected light to light of a wavelength ranging between a second upper limit and a second lower limit, where the second set of limits at least partially overlap the first set of limits.

9. Image capture apparatus as claimed in claim 1, characterised in that the blocking means includes means capable of restricting the angle of linear polarisation of the collected light to light having a first angle of polarisation.

10. Image capture apparatus as claimed in claim 1, characterised in that the emission means includes means capable of restricting the angle of linear polarisation of the light to light having a second angle of polarisation, substantially perpendicular to the first angle of polarisation, so that in use the intensity of specular reflections is reduced.

11. Image capture apparatus as claimed in claim 1, characterised in that the blocking means comprises means to capture a pair of images of the object; only one of which is illuminated by light emitted by the means capable of emitting light, and subtracting one image from the other image, thereby deriving the difference between the two, so that the difference image incorporates the illumination derived from the emitted light.

12. Image capture apparatus as claimed in claim 7, characterised in that the flash lamp is provided with a reflector optimised for high reflection in the near infra-red range, employing a gold reflecting surface.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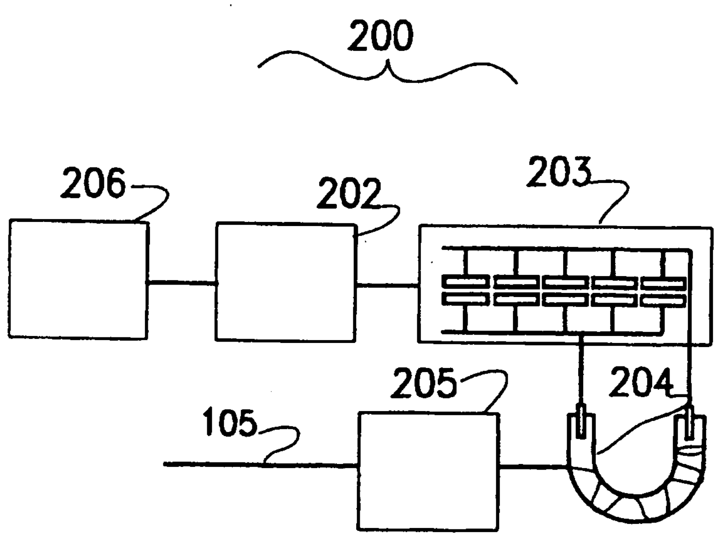
112
104
101
102
103
106
105
107
108
109
110
111

Fig 1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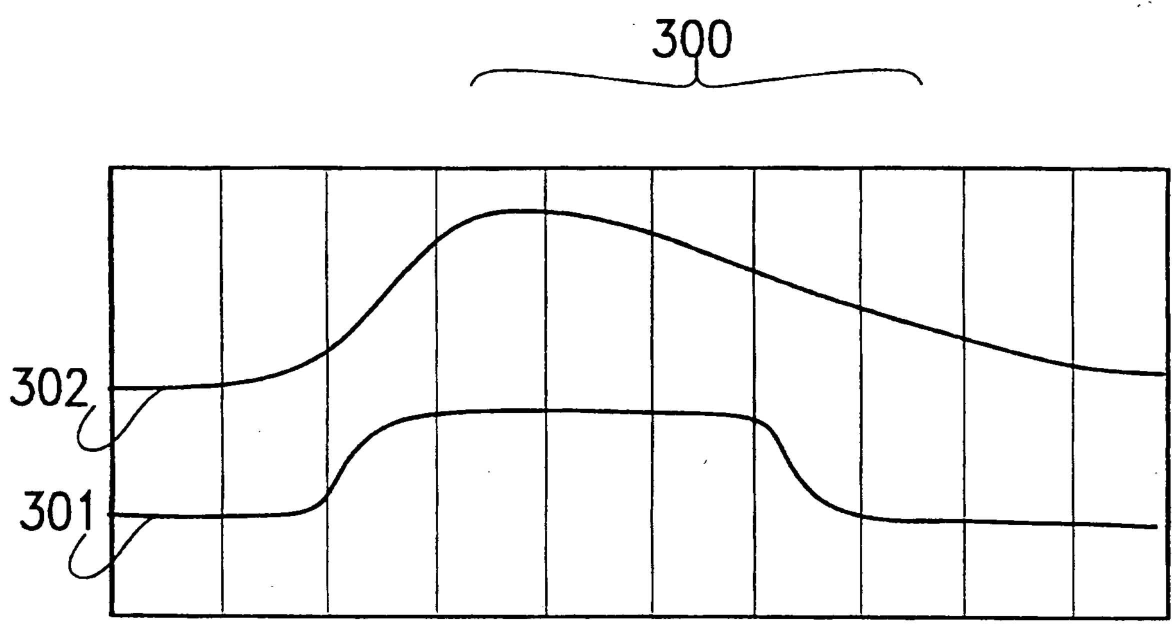
205
204
105

Fig 2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302
301

Fig 3

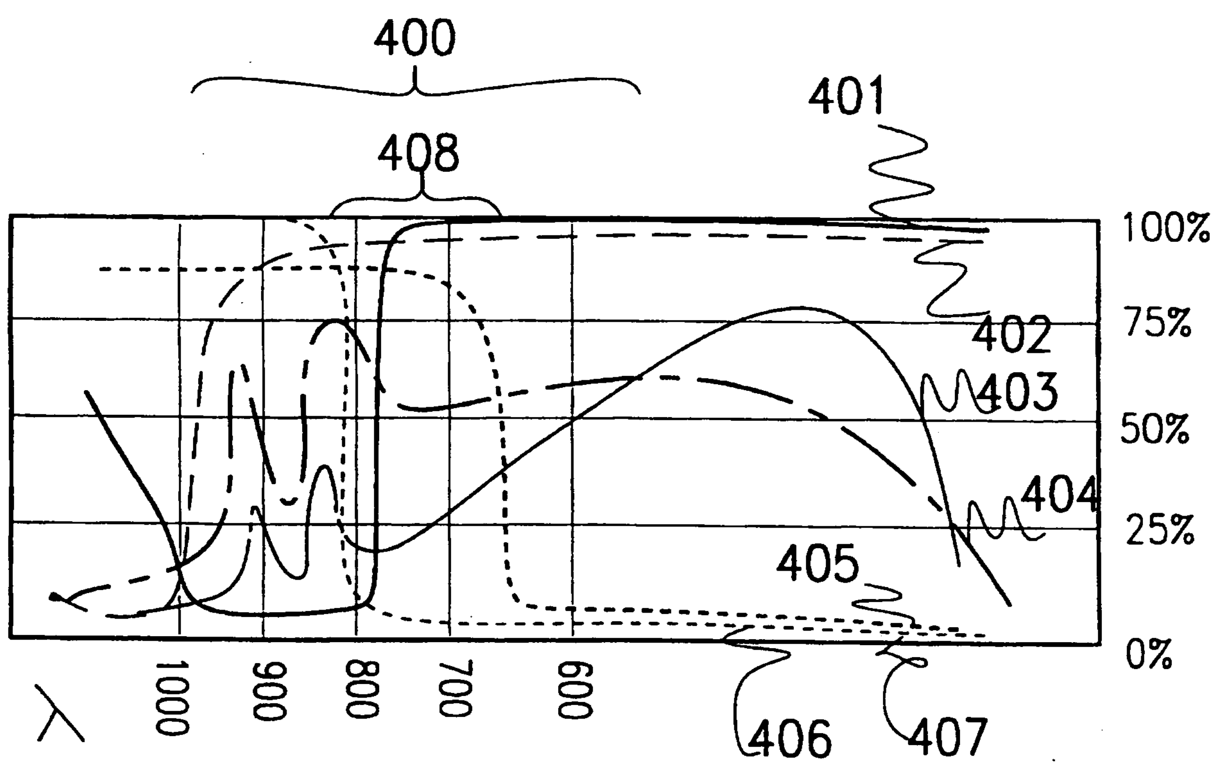
400
408
401
402
403
404
405
406
407
100%
75%
50%
25%
0%
1000
900
800
700
600
λ

Fig 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/NZ96/00109

A. CLASSIFICATION OF SUBJECT MATTER
IPC(6) :H04N 7/18
US CL :348/86
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
U.S. : Please See Extra Sheet.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS, DIALOG

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X --- Y	US, A, 5,138,459 (ROBERTS ET AL) 11 AUGUST 1992, FIGS. 2 AND 4-6.	1 --- 2, 4, 6, AND 8
Y	US, A, 5,248,880 (FERGASON) 28 SEPTEMBER 1993, FIGS. 2, 3, 5, AND 6.	2-12
Y	US, A, 5,095,252 (KURTH) 10 MARCH 1992, FIGS. 1-5.	2-12
A	US, A, 5,497,188 (KAYE) 05 MARCH 1996.	1-12
A	US, A, 4,575,849 (CHUN) 11 MARCH 1986.	1-12

[X] Further documents are listed in the continuation of Box C. [ ] See patent family annex.

* Special categories of cited documents:
- "A" document defining the general state of the art which is not considered to be part of particular relevance
- "E" earlier document published on or after the international filing date
- "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
- "O" document referring to an oral disclosure, use, exhibition or other means
- "P" document published prior to the international filing date but later than the priority date claimed
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- "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
- "&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
14 APRIL 1997	08 MAY 1997

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